

AD

AD-E403 290

Technical Report ARMET-TR-09049

## M228 FUZE IGNITER PRESSURE MEASUREMENT PART 1

Eugene Homentowski  
Neha Mehta  
Gartung Cheng  
Emily Cordaro

July 2010

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND  
ENGINEERING CENTER

Munitions Engineering Technology Center

Picatinny Arsenal, New Jersey



Approved for public release; distribution is unlimited.

20100820114

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

The citation in this report of the names of commercial firms or commercially available products or services does not constitute official endorsement by or approval of the U.S. Government.

Destroy this report when no longer needed by any method that will prevent disclosure of its contents or reconstruction of the document. Do not return to the originator.

## REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-01-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden to Department of Defense, Washington Headquarters Services Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.  
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) July 2010	2. REPORT TYPE	3. DATES COVERED (From - To) June to September 2008		
4. TITLE AND SUBTITLE  M213 FUZE IGNITER PRESSURE MEASUREMENT, PART 1		5a. CONTRACT NUMBER		
		5b. GRANT NUMBER		
		5c. PROGRAM ELEMENT NUMBER		
6. AUTHORS  Eugene Homentowski, Neha Mehta, Gartung Cheng, and Emily Cordaro		5d. PROJECT NUMBER		
		5e. TASK NUMBER		
		5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC, METC Energetics, Warheads & Manufacturing Technology Directorate (RDAR-MEE-W) Picatinny Arsenal, NJ 07806-5000		8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC, ESIC Knowledge & Process Management (RDAR-EIK) Picatinny Arsenal, NJ 07806-5000		10. SPONSOR/MONITOR'S ACRONYM(S)		
		11. SPONSOR/MONITOR'S REPORT NUMBER(S) Technical Report ARMET-TR-09049		
12. DISTRIBUTION/AVAILABILITY STATEMENT  Approved for public release; distribution is unlimited.				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT  The M67 hand grenade is a traditional pull-pin grenade, widely used by the U.S. Army and Marine Corps. Pulling the pin in the grenade's fuze (the M213) releases the spoon and the hammer, which hits the primer at the top of the fuze body initiating the delay firing train (C70 det). This fuze train is simple and has functioned well and reliably in grenades for decades. Unfortunately, it also has major safety issues. Any unwanted stimulus that causes the primer to function, like fire, initiates the entire fuze train. The large quantities of primary explosive in the detonator can also be detonated by external stimulus with enough energy to function the entire grenade. This report describes the tests that were conducted to measure the pressure generated when the primer was ignited by removing the pin and allowing the striker to impact the primer. This was done with training round fuze, M228, which has same primer and delay element.				
15. SUBJECT TERMS  M67 grenade      M228 and M213 fuze      Pressure				
16. SECURITY CLASSIFICATION OF:		17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Neha Mehta
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U	SAR 23	19b. TELEPHONE NUMBER (Include area code) (973) 724-2912

## **ACKNOWLEDGMENTS**

U.S. Army Armament Research, Development and Engineering Center, Picatinny Arsenal, New Jersey personnel who were involved in making the pressure measurements were from the Explosives Development Branch and Warheads Branch of the Munitions Engineering Technology Center. Engineers from PCB who were consulted were Rick Bovenkerk and Tom Glenn.

## CONTENTS

	Page
Introduction	1
Test Descriptions	1
Results	5
Conclusions	16
Preliminary Tests	16
Final Tests	16
Recommendations	16
Distribution List	17

## FIGURES

1	M213 and M228 fuze	1
2	Fuze igniter head, fixtures, pressure sensor	2
3	System block diagram	2
4	Preassembled components	3
5	Assembled components	3
6	Test assembly in chamber	3
7	Test chamber	4
8	Test instrumentation	4
9	Pressure signals, recessed fixture	4
10	Pressure signals, flush fixture, vinyl tape	6
11	Pressure signals, flush fixture, grease	6
12	Pressure signals, test 1-4	8
13	Pressure signals, test 5-8	8
14	Pressure signals, test 9-12	9
15	Pressure signals, test 13-16	9

**FIGURES**  
(continued)

	Page
16 Pressure signals, test 17-20	9
17 Pressure signals, test 21-24	10
18 Pressure signals, test 25-28	10
19 Pressure signals, test 29-32	10
20 Pressure signals, test 33-36	11
21 Pressure signals, test 37-40	11
22 Pressure signals, test 41-44	11
23 Pressure signals, test 45-48	12
24 Pressure signals, test 49-52	12
25 Pressure signals, test 53-56	12
26 Pressure signals, test 57-60	13
27 Pressure signals, test 61-64	13
28 Milliwell pressure test, filtered and unfiltered signal	

**TABLES**

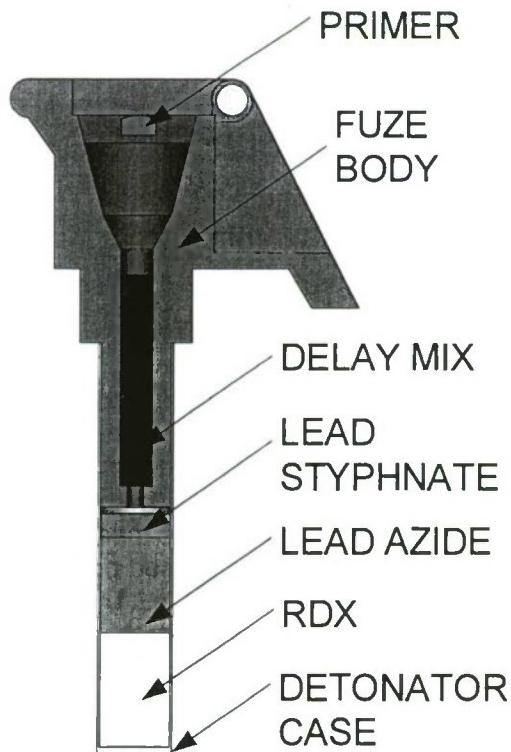
1 Peak pressures, fixture 1 (discounted initial pulses) and fixture 2	7
2 Peak pressures with rise time of the waveforms	14

## INTRODUCTION

The M67 fragmentation hand grenade is a traditional pull-pin grenade, widely used by the U.S. Army and Marine Corps. Pulling the pin in the grenade's fuze (the M213) releases the spoon and the hammer, which hits the primer at the top of the fuze body (fig. 1), initiating the firing train. The delay mix is ignited by the primer and burns several seconds before initiating the attached C70 detonator. This detonator is massive, containing approximately 10 times more lead styphnate, lead azide, and RDX than other detonators. This size is not simply a case of over engineering; the length is required to properly initiate the grenade's explosive fill for good fragmentation, while its diameter is dictated by the dimensions of the fuze body.

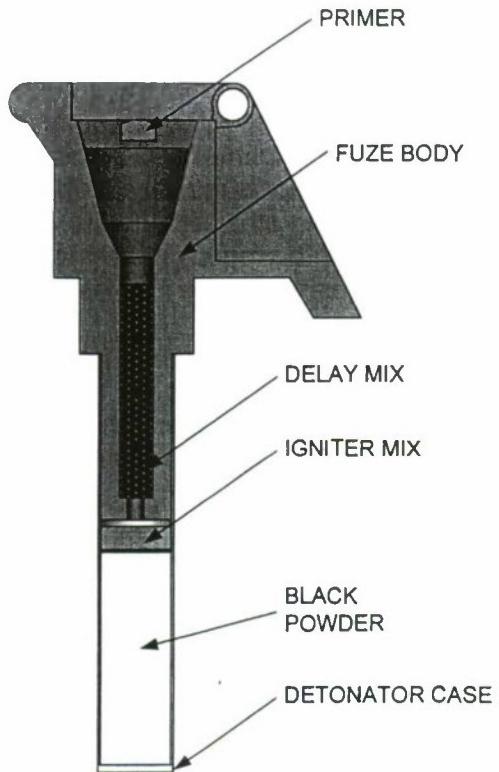
The M228 is also the grenade's fuze, which is used for training rounds. It has the same primer element at the top of the fuze body, initiating the firing train. The delay mix is ignited by the primer and burns several seconds before initiating the detonator, which only contains black powder compared to primary/secondary material, lead azide/RDX.

Pressure measurement tests were setup to determine the pressure generated when the primer was ignited when the pin was removed and the striker hit the primer. A total of 23 preliminary tests were made with two different fixtures before the most suitable fixture, test methodology, and generated pressure levels were determined. Sixty-four tests were then conducted after selecting the fixture and test method.



a) M213 fuze

Figure 1  
M213 and M228 grenade fuze  
(spoon and hammer not pictured)



b) M228 fuze

Figure 1  
(continued)

## TEST DESCRIPTION

The M228 fuze igniter head and the two fixtures used to conduct pressure tests on the head are shown in figure 2. The head, which was modified by removing the delay tube, contains only the filled primer cup. It was screwed into the top of the fixture until it contacted a flat surface machined into the fixture. Teflon tape was wrapped around the head threads to seal against pressure leakage. Below the flat surface, the fixture was machined to accept a PCB model P119B12 pressure sensor. The first fixture had a recessed pressure sensor with a 5/16 in. gap between the igniter head and the sensor's active surface. This gap was filled by a steel pellet that was included to protect the sensor against heat from the burning igniter. The sensor is shown in figure 2 and the block diagram of the measurement system is shown in figure 3. Figures 4 through 8 show the assembled test unit, the test chamber, and instrumentation used to measure pressure. The test was conducted with the item in the small containment chamber (fig. 7). A string was tied to the safety pin. This string was drawn outside of one of the chamber ports so it could initiate in the closed chamber and it's safe. The string was pulled from outside, which pulled the pin to strike and hit the primer. Pulling the pin allowed the striker to hit the primer, igniting it, and generating pressure. The pressure was sensed by the pressure sensor, which sent a signal to a PCB model 402M186 inline amplifier and PCB model 482A22 signal

conditioner. The signal was then sent to a LeCroy model 6050A digital storage oscilloscope where it was captured and stored. Waveforms from the 12 tests conducted with the first fixture are shown in figure 9. The waveforms were consistent, typically having an initial pulse of 220 to 390 mV peak (5326 to 9442 psi peak) and 20  $\mu$ s duration, followed by a smaller step signal with an initial peak of 26 to 86 mV (629 to 2082 psi) that gradually diminished towards zero as the pressure leaked from the fixture cavity. The calibration factor for this PCB system was 24.21 psi/mV.

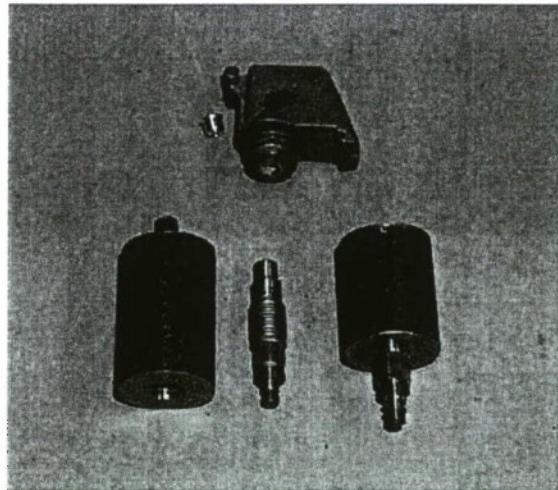


Figure 2  
Fuze igniter head, fixtures, pressure sensor



Figure 3  
System block diagram

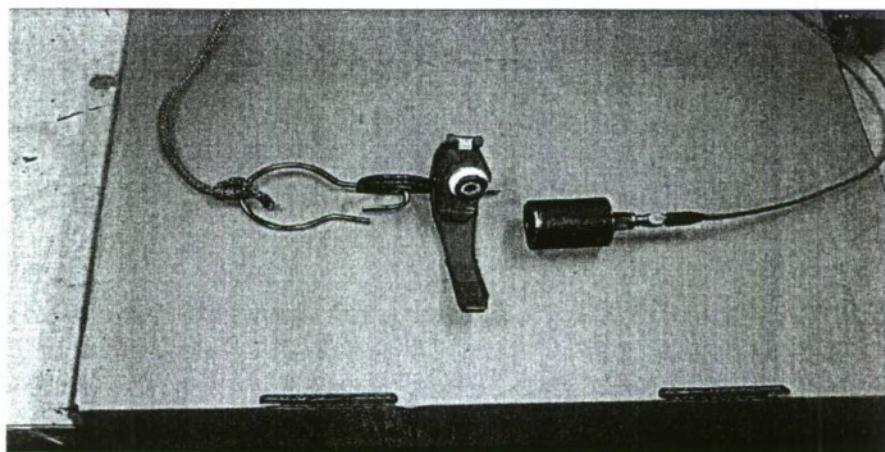


Figure 4  
Preassembled components

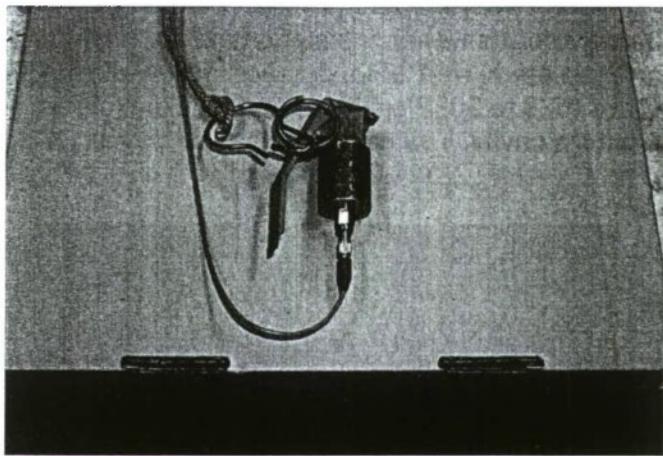


Figure 5  
Assembled components

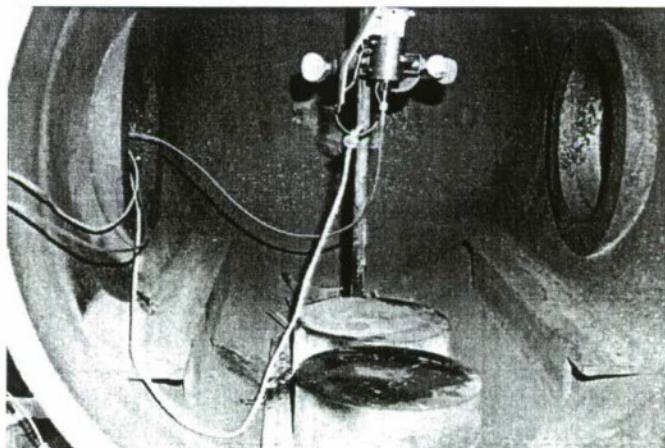


Figure 6  
Test assembly in chamber

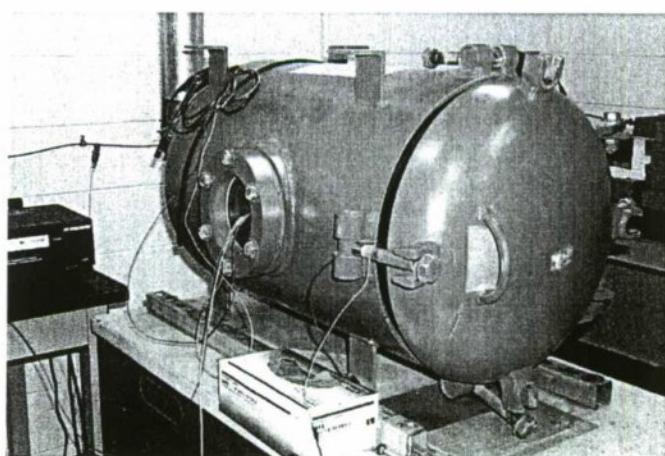


Figure 7  
Test chamber

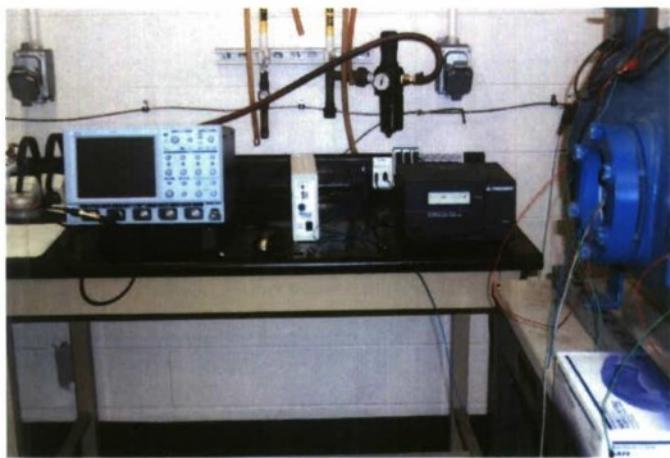


Figure 8  
Test instrumentation

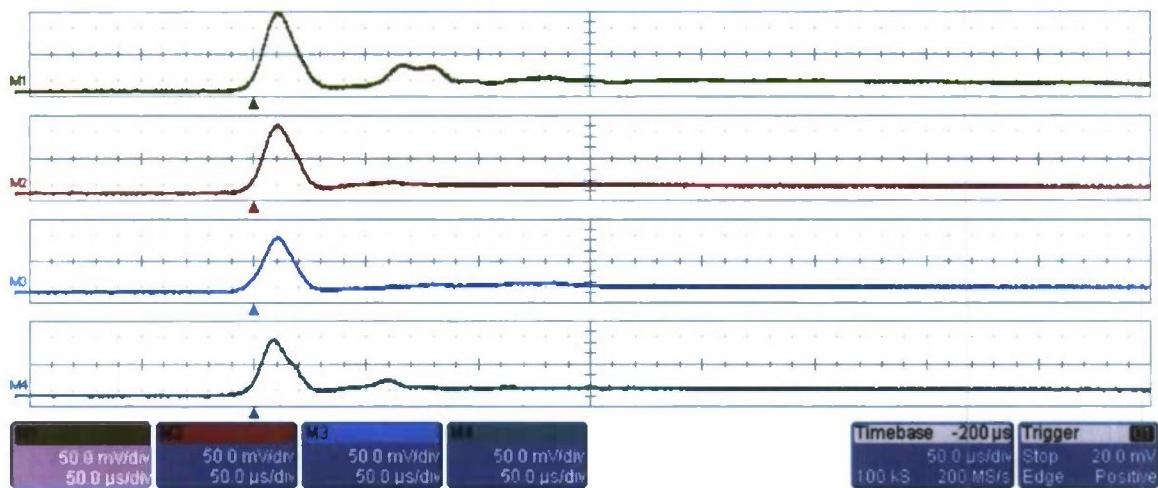
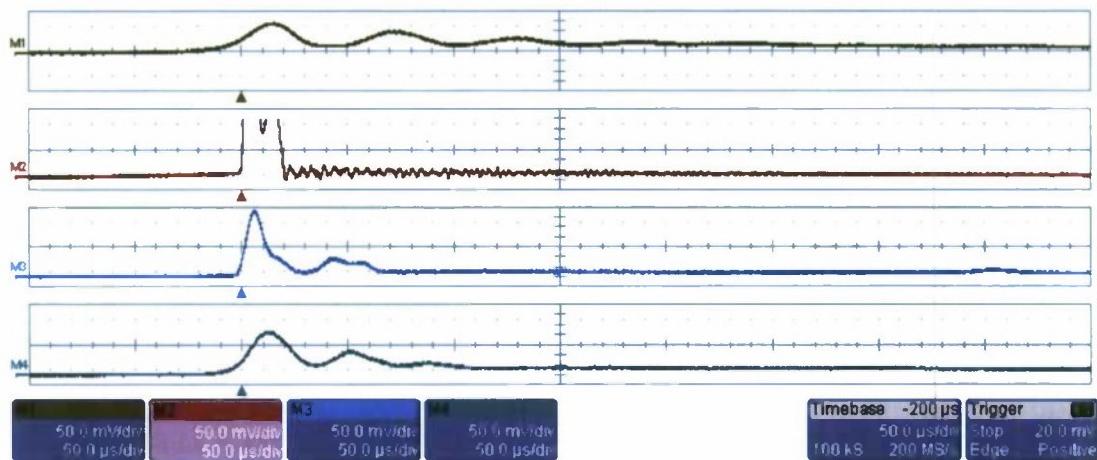


Figure 9  
Pressure signals, recessed fixture

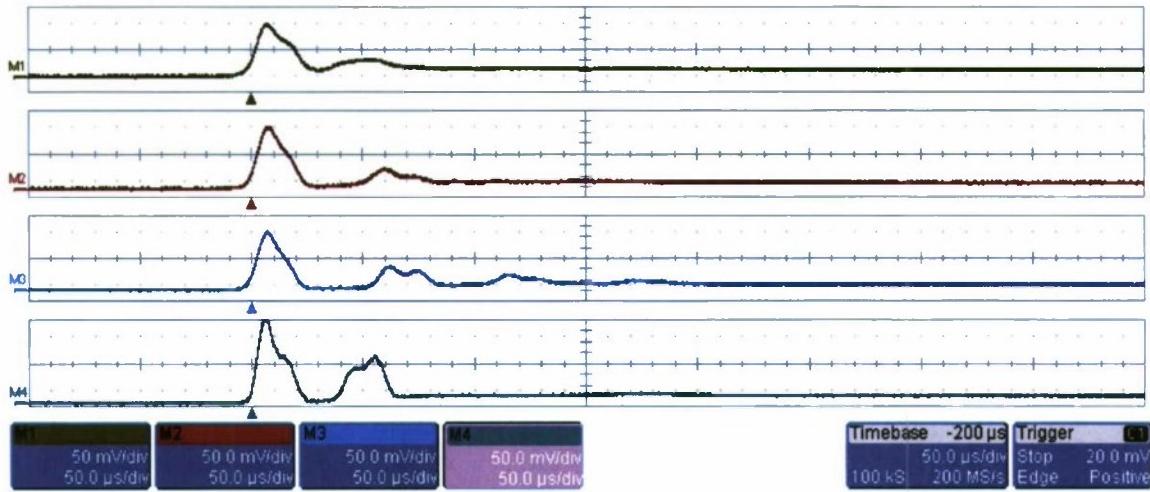


Figure 9  
(continued)

## RESULTS

Eleven tests were conducted with the second fixture which was designed to eliminate the large gap between the ignition head and sensor diaphragm. This fixture was machined so that the sensor diaphragm was almost flush with the flat surface in contact with the fuze head. The head diaphragm gap was approximately 0.010 in. Temperature protection was provided by vinyl tape for four tests and silicone grease for seven tests. The test methodology was the same for the second fixture as for the first fixture. Figure 10 shows the waveforms obtained for the tests conducted with vinyl tape placed across the sensor diaphragm. Those signals were not the same as the signals obtained with the first fixture. The second fixture signals did not have a pulse initially, but were step waveforms that were 54 to 76 mV peak (1307 to 1840 psi peak), which were similar to the step signals obtained with the first fixture that occurred after the first large pulse. PCB Engineers were asked if they could explain the presence of the first pulse in the first fixture tests. They were unable to come up with an explanation and no one involved with these tests could explain it either. However, the PCB engineers thought that the second fixture, with the flush diaphragm, should give the most accurate signals and they recommended using silicone grease or vinyl tape to protect the sensor. This was done for the next four tests where grease was placed in the airspace from the bottom of the truncated igniter head to the top of the channel where the delay composition normally goes (the delay composition was removed from the heads for all the tests to be conducted in this series). The waveforms obtained from these tests (fig. 11) are very similar to the three vinyl tape waveforms with peaks of 41 to 81 mV (993 to 1961 psi). The first signal (fig. 11) was obtained using the recessed fixture as a check on the sensor operation. The last three tests were made using twice the amount of grease to fill the head cavity. This was done to see if it would produce twice the signal peak, but results were inconclusive. However, the waveforms were similar with peaks of 39 to 111 mV (944 to 2687 psi). Table 1 summarizes the peak pressures obtained with fixture 1, which discounted the initial pulses, and fixture 2. These tests completed the exploratory phase of this project.

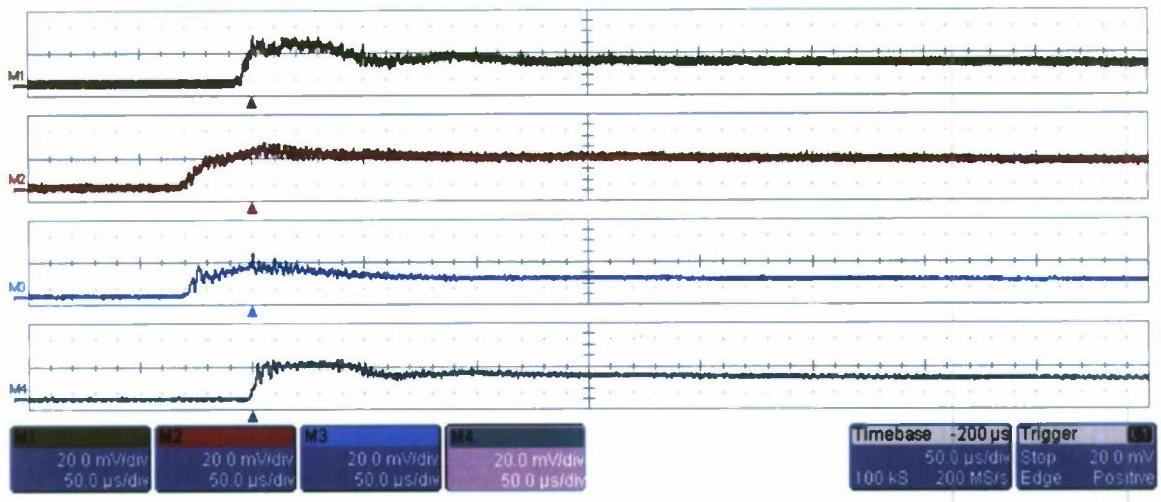


Figure 10  
Pressure signals, flush fixture, vinyl tape

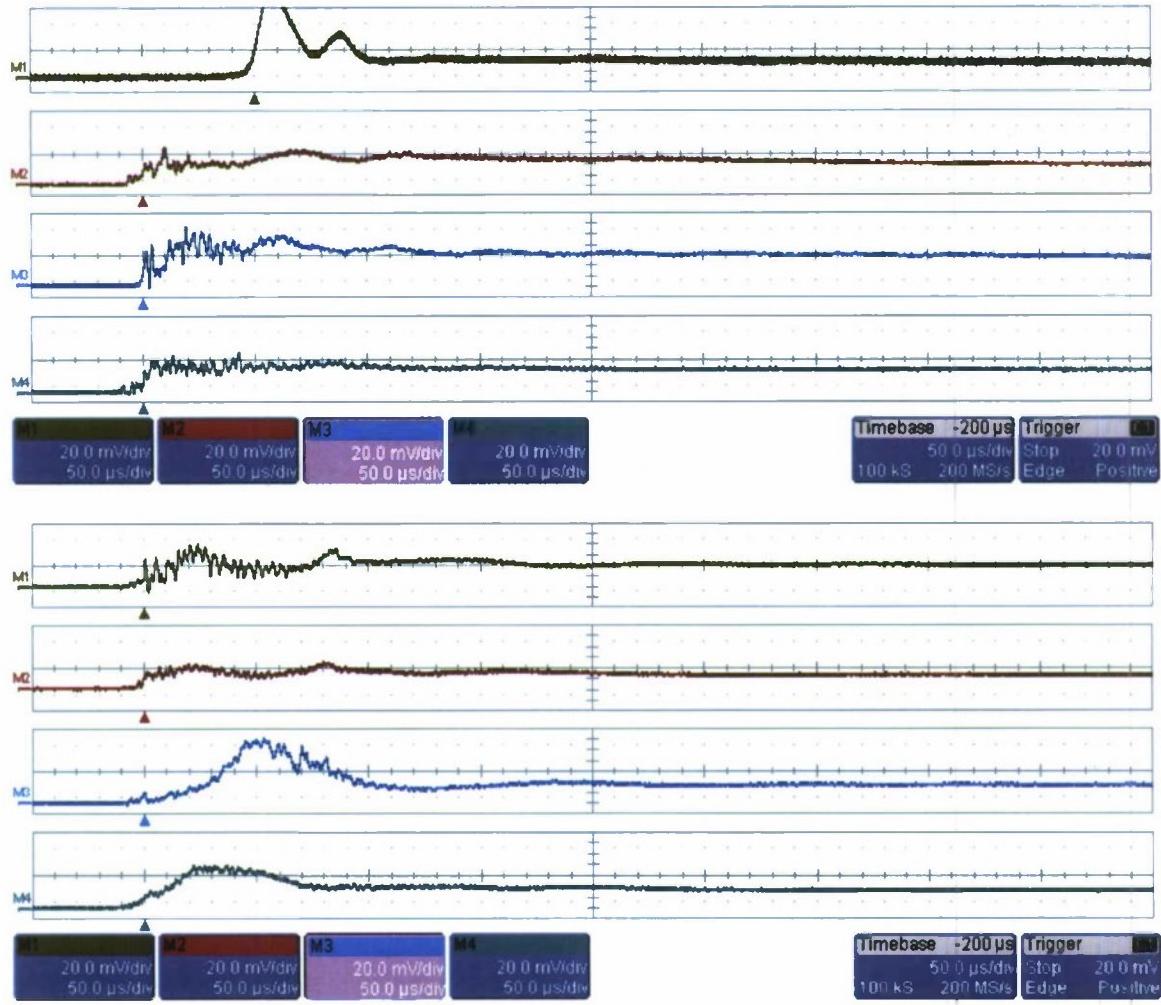
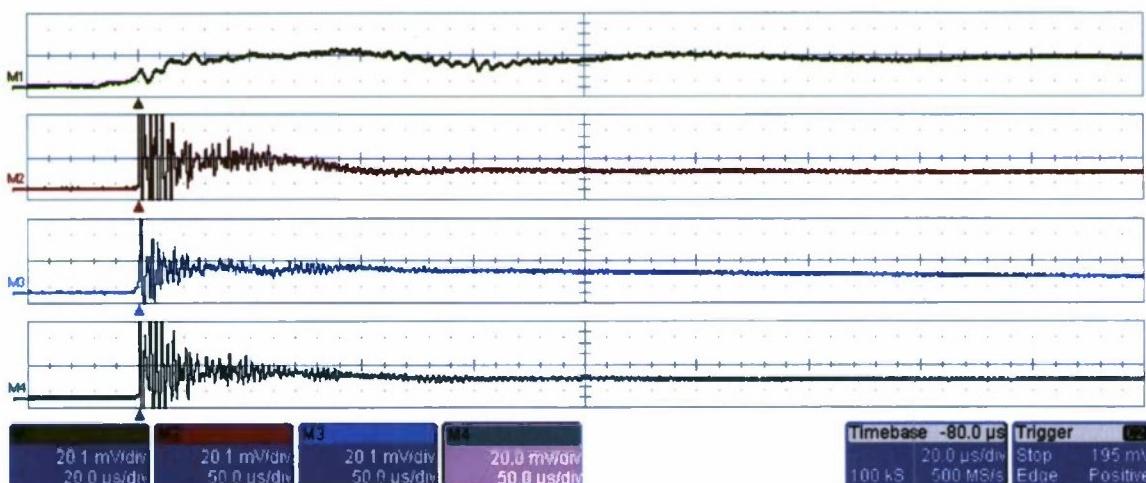


Figure 11  
Pressure signals, flush fixture, grease

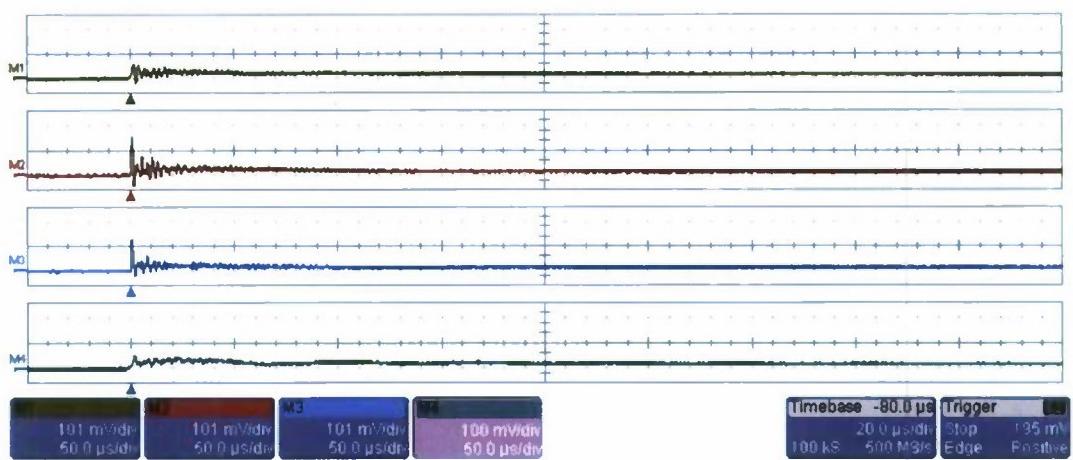
**Table 1**  
**Peak pressures, fixture 1 (discounted initial pulses) and fixture 2**

Signal	Conditions	Peak pressure (psi)
Fig. 9, M1	Recessed fixture w/steel pellet	1210
M2	Recessed fixture w/steel pellet	629
M3	Recessed fixture w/steel pellet	2082
M4	Recessed fixture w/steel pellet	920
M1	Recessed fixture w/steel pellet	1501
M2	Recessed fixture w/steel pellet	1210
M3	Recessed fixture w/steel pellet	1017
M4	Recessed fixture w/steel pellet	968
M1	Recessed fixture w/steel pellet	1017
M2	Recessed fixture w/steel pellet	872
M3	Recessed fixture w/steel pellet	920
M4	Recessed fixture w/steel pellet	920
Fig. 10, M1	Flush fixture w/vinyl tape	1840
M2	Flush fixture w/vinyl tape	1767
M3	Flush Fixture w/vinyl tape	1307
M4	Flush fixture w/vinyl tape	1549
Fig. 11, M1	Recessed fixture w/steel pellet	944
M2	Flush fixture w/grease	993
M3	Flush fixture w/grease	1961
M4	Flush fixture w/grease	1210
M1	Flush fixture w/grease	1501
M2	Flush fixture w /2x grease	944
M3	Flush fixture w/2x grease	2687
M4	Flush fixture w/2x grease	1743

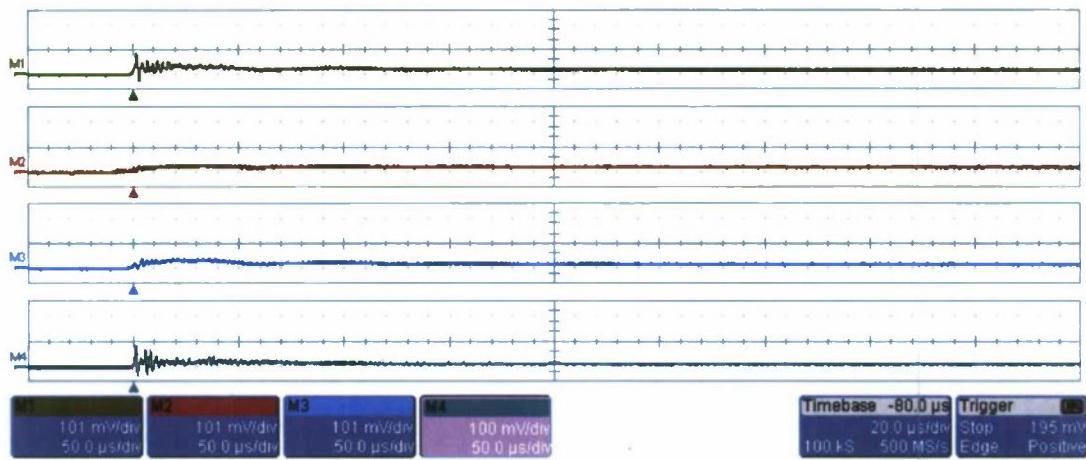
Sixty-four tests were then performed using the flush fixture with vinyl tape over the sensor surface. Figures 12 through 28 show the pressure waveforms obtained from the 64 test items of this second group. Table 2 lists the peak pressures and rise times of the waveforms.



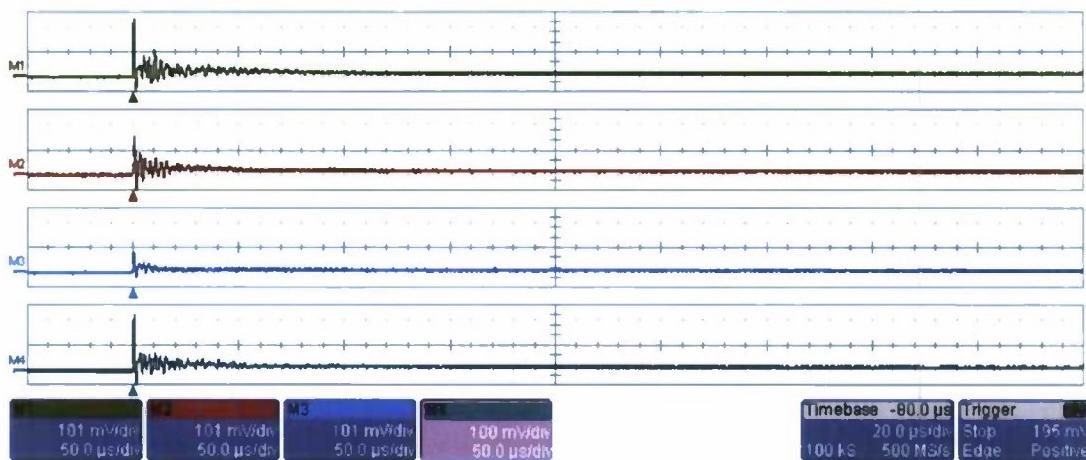
**Figure 12**  
**Pressure signals, test 1-4**



**Figure 13**  
Pressure signals, test 5-8



**Figure 14**  
Pressure signals, test 9-12



**Figure 15**  
Pressure signals, test 13-16

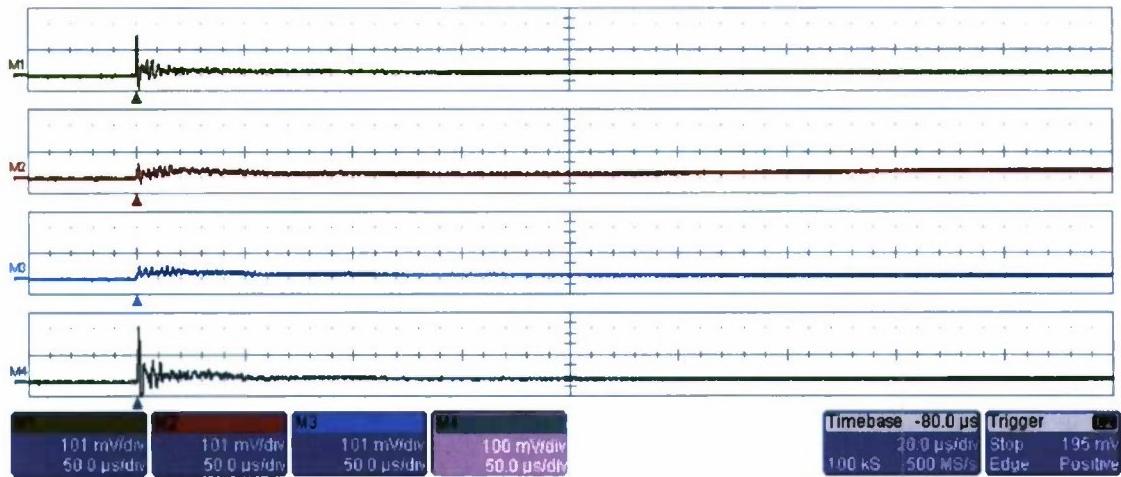


Figure 16  
Pressure signals, test 17-20

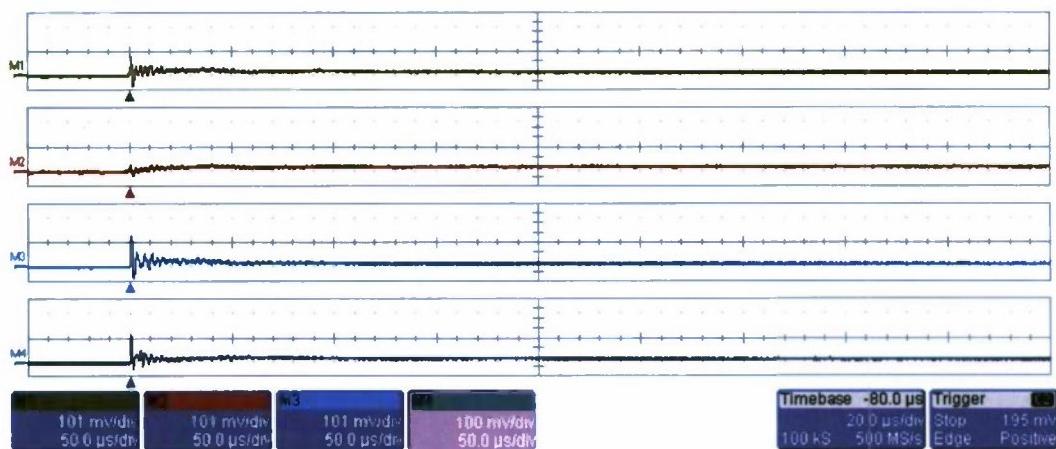


Figure 17  
Pressure signals, test 21-24

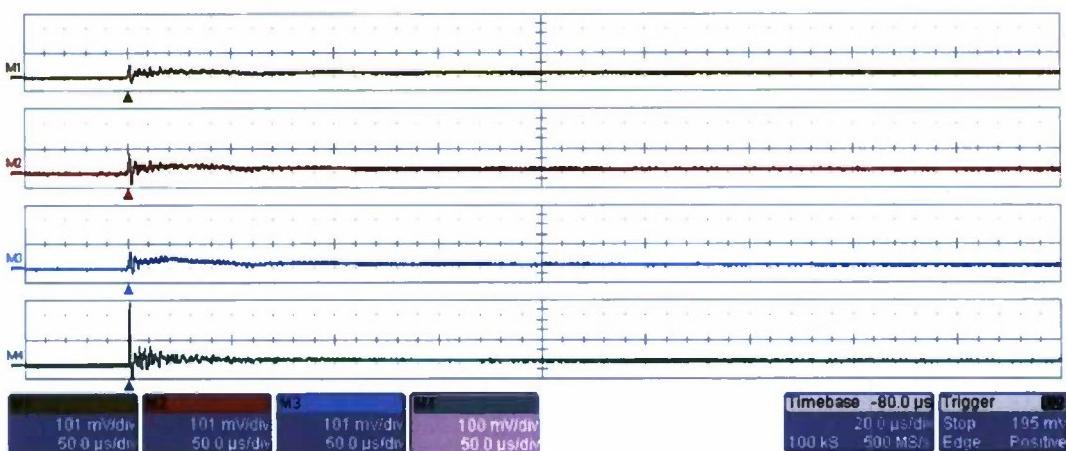
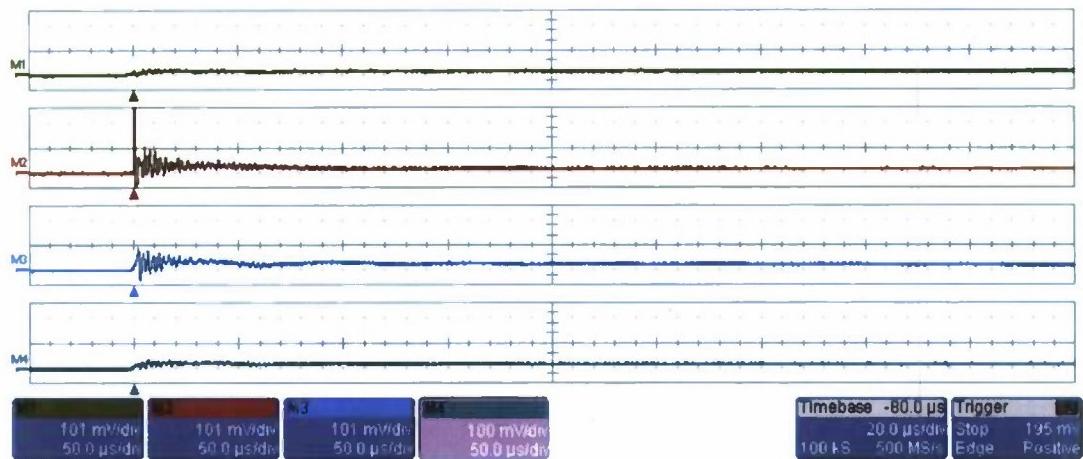
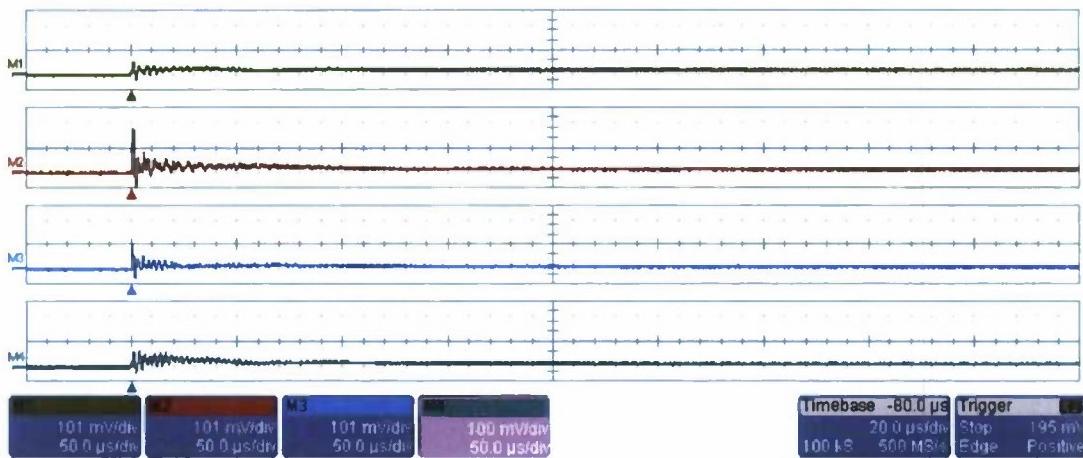


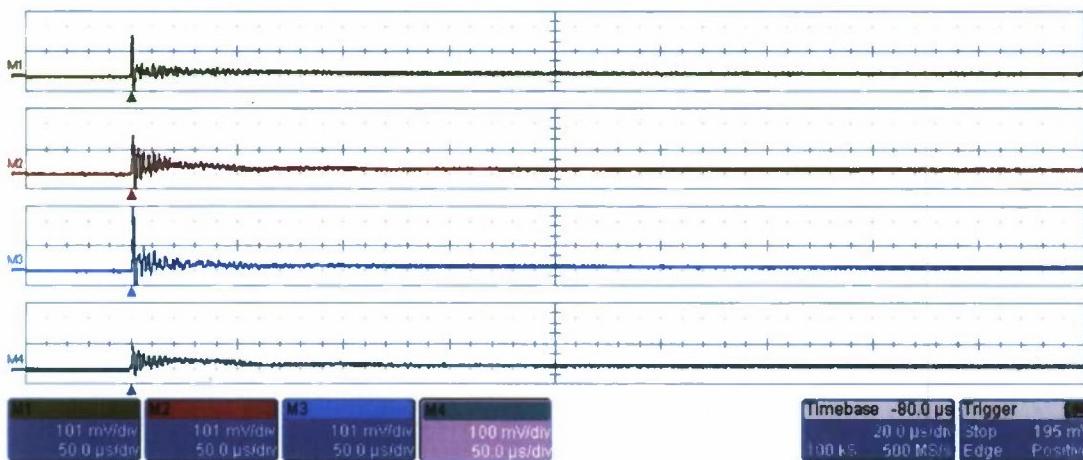
Figure 18  
Pressure signals, test 25-28



**Figure 19**  
Pressure signals, test 29-32



**Figure 20**  
Pressure signals, test 33-36



**Figure 21**  
Pressure signals, test 37-40

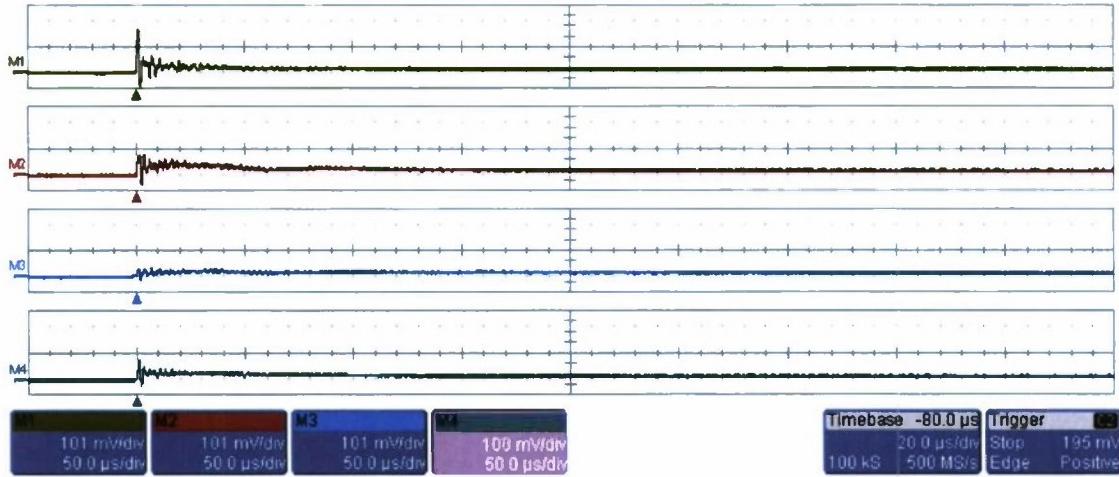


Figure 22  
Pressure signals, test 41-44

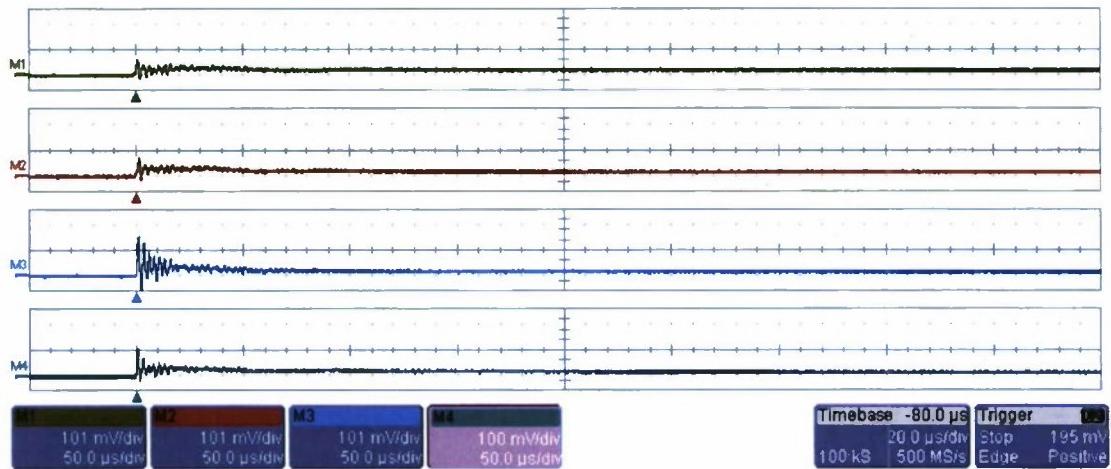


Figure 23  
Pressure signals, test 45-48

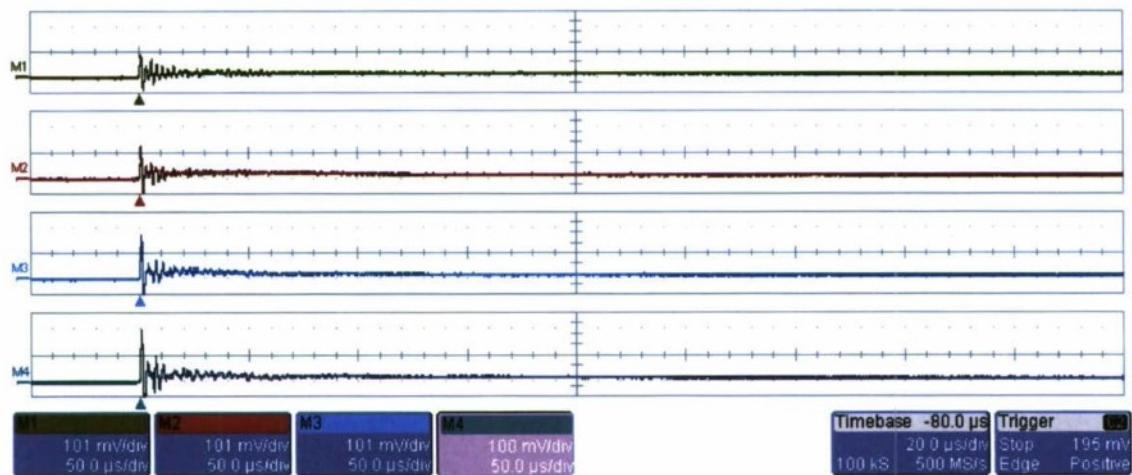


Figure 24  
Pressure signals, test 49-52

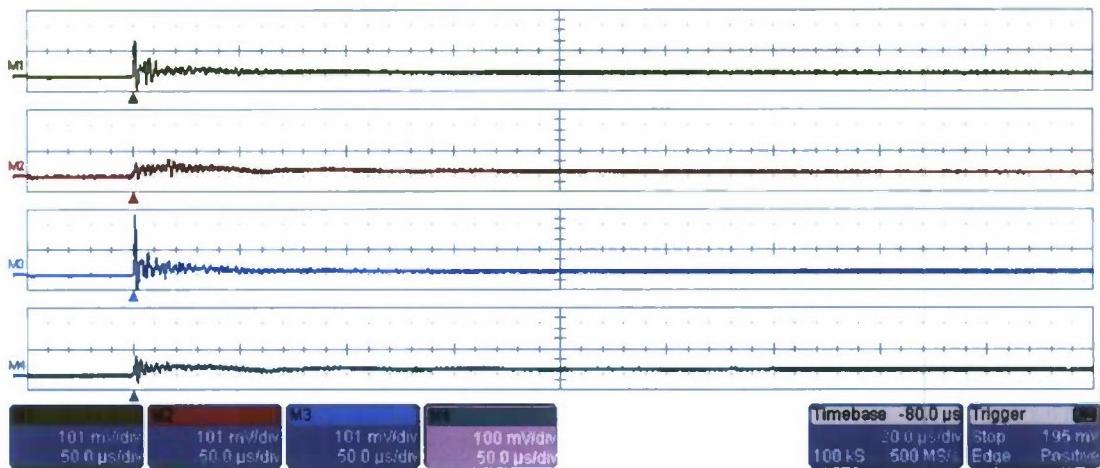


Figure 25  
Pressure signals, test 53-56

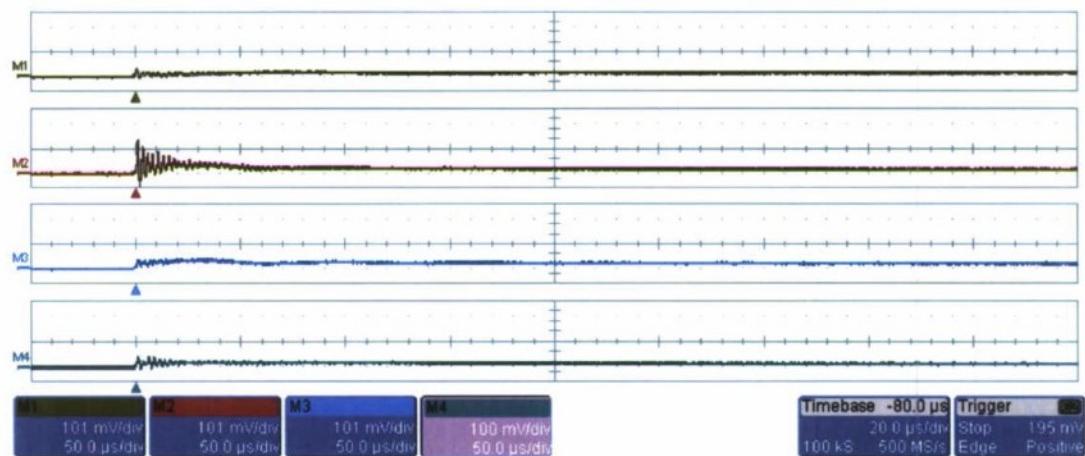


Figure 26  
Pressure signals, test 57-60

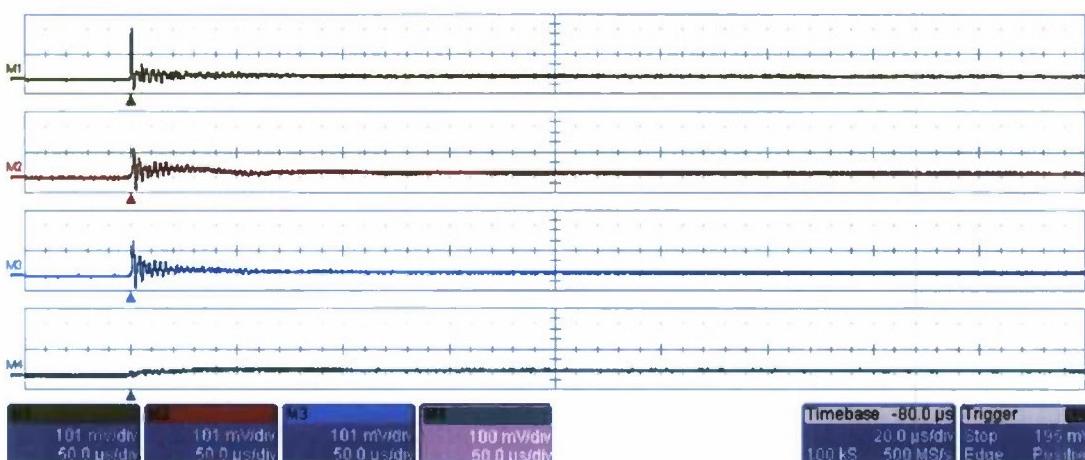


Figure 27  
Pressure signals, test 61-64

Table 2  
Peak pressures with rise time of the waveforms

Test number	Initial peak pressure (psi)	Initial peak rise time (μs)
1	1700	31
2	4100	0.6
3	4100	1.5
4	Off Scale	na
5	3500	1.0
6	3500	2.0
7	3500	2.0
8	7500	0.4
9	3200	2.8
10	1500	20
11	2200	5.0
12	5200	1.0
13	13800	0.38
14	9000	0.65
15	4600	0.54
16	1400	0.45
17	9200	0.36
18	3200	0.98
19	2700	1.5
20	12100	0.73
21	4600	0.94
22	1700	0.68
23	7500	0.78
24	6500	0.44
25	2900	1.2
26	4400	0.84
27	4200	1.2
28	15000	0.38
29	970	2.7
30	16500	0.3
31	5300	2.4
32	1500	3.3
33	2800	1.2
34	10300	0.95
35	6100	0.58
36	3600	1.7
37	9800	0.3
38	9000	0.7
39	15300	0.68
40	5200	0.82
41	9900	0.89
42	4200	0.94
43	1700	1.6
44	4400	0.91
45	3500	0.94
46	4000	1.4
47	9200	0.96
48	6300	0.48
49	5200	0.9

Table 2  
(continued)

Test number	Initial peak pressure (psi)	Initial peak rise time (μs)
50	7500	0.78
51	10000	0.82
52	11700	0.72
53	8200	0.89
54	3000	1.7
55	14400	0.63
56	4500	0.92
57	1900	1.3
58	8000	1.1
59	2100	1.6
60	2400	1.2
61	12100	0.4
62	7000	1.6
63	8500	1.4
64	1500	28

Most of the waveforms have an exponentially damped oscillation of about 500 KHz at the start of the signal. It is believed the oscillations were caused by the resonance of the pressure sensor that distorts the signal in that fashion. Future tests should be conducted with a 100 KHz low pass filter inserted at the output of the signal chain. As far as the 64 tests already conducted are concerned, an arbitrary function generator can be used to reproduce the original signals and pass them through the 100 KHz filter before capturing them with an oscilloscope. Figure 28 shows a pressure signal before and after filtering. The signal was obtained from a different type of explosive reaction using the 119B pressure sensor. An arbitrary function generator is currently on order for this group.

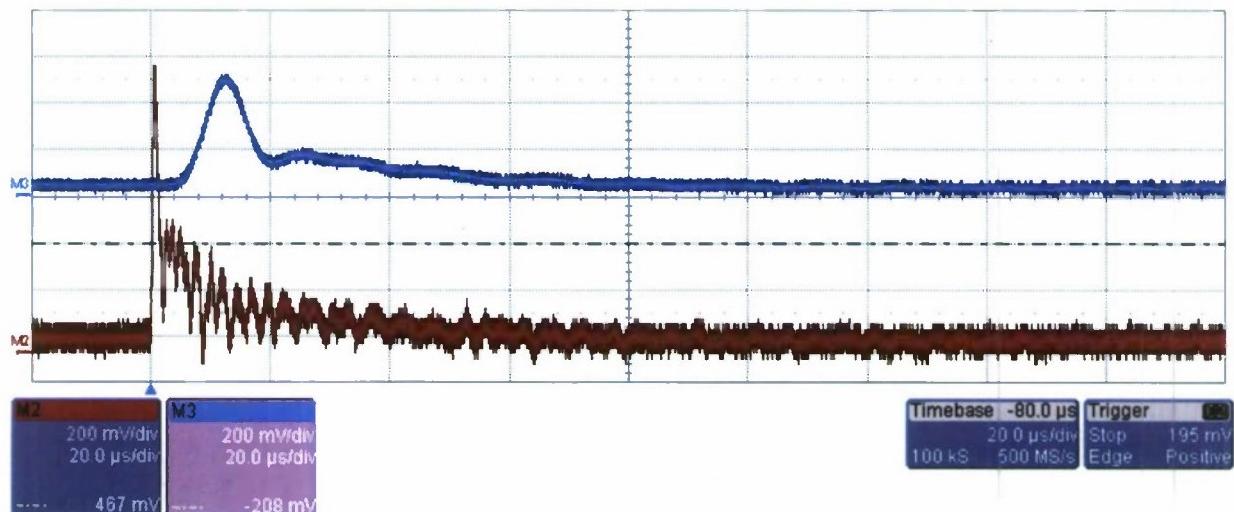


Figure 28  
Milliwell pressure test, filtered and unfiltered signal

## **CONCLUSIONS**

### **Preliminary Tests**

There was a considerable variation in the test results from both fixtures. The fixture with the recessed pressure gauge and steel pellet produced a large initial pulse the cause of which could not be determined. The fixture with the flush pressure gauge was better suited to make the pressure measurements. Peak pressures generated by the primer composition in the flush fixture ranged from 944 psi to 2687 psi. Tests with the vinyl tape gave higher pressures with less variation. There was too much variation in the length of the truncated head.

### **Final Tests**

Peak pressures ranged from 970 psi to 16,500 psi. Rise times were from 0.3  $\mu$ s to 28  $\mu$ s. There was considerable variation in pressures for the final tests also. The test method did not address the cause of this variation.

## **RECOMMENDATIONS**

Use the flush fixture for future tests with vinyl tape over the sensor head. Machine the head to a uniform length. Add a 100 KHz low pass filter at the output of the signal chain to reduce effects of sensor resonance.

## DISTRIBUTION LIST

Commander  
RDECOM  
U.S. Army Tank-automotive and Armaments Center  
ATTN: RDAR-EIK  
RDAR-GC  
RDAR-MEE-W, N. Mehta (7)  
Picatinny Arsenal, NJ 07806-5000

Defense Technical Information Center (DTIC)  
ATTN: Accessions Division  
8725 John J. Kingman Road, Ste 0944  
Fort Belvoir, VA 22060-6218

Commander  
Soldier and Biological/Chemical Command  
ATTN: AMSSB-CII, Library  
Aberdeen Proving Ground, MD 21010-5423

Director  
U.S. Army Research Laboratory  
ATTN: AMSRL-CI-LP, Technical Library  
Bldg. 4600  
Aberdeen Proving Ground, MD 21005-5066

Chief  
Benet Weapons Laboratory, WSEC  
U.S. Army Research, Development and Engineering Command  
Armament Research, Development and Engineering Center  
ATTN: RDAR-WSB  
Watervliet, NY 12189-5000

Director  
U.S. Army TRADOC Analysis Center-WSMR  
ATTN: ATRC-WSS-R  
White Sands Missile Range, NM 88002

Chemical Propulsion Information Agency  
ATTN: Accessions  
10630 Little Patuxent Parkway, Suite 202  
Columbia, MD 21044-3204

GIDEP Operations Center  
P.O. Box 8000  
Corona, CA 91718-8000